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Skeletal malformations in Australian marine finfish hatcheries

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ABSTRACT

The Australian finfish aquaculture industry has a target to more than treble production from 2005 to 100,000 t p.a. by 2015. Most of the current production is from sea cage culture of *Salmo salar* and *Thunnus maccoyii* but new and emerging species are predicted to have a faster increase in production and were the focus of this study. The quantity and quality of hatchery-produced fingerlings is an impediment to achieving growth in the marine finfish sector. A survey of 18 hatcheries revealed that 44% indicated skeletal malformations were a significant issue in hatchery production, and 89% reported variability in malformation rates between production batches. Samples of fish from selected hatcheries were cleared and stained for assessment of abnormal bone development. Two hatcheries that had indicated malformations were not a significant problem submitted samples with >5% severe malformations. Jaw and spinal malformations occurred in *Lates calcarifer*, *Seriola lalandi*, *Epinephelus fuscoguttatus*, *E. coioides*, and *Latris lineata*. To the best of our knowledge, causative factors of malformations in Australian hatcheries have only been identified for jaw malformation in *Lates calcarifer* and *Latris lineata*, and further research is either needed or underway with other species and malformation types in order to improve culture protocols and increase fingerling quality. Improved monitoring techniques for skeletal malformations would substantially enhance the comparison of production methods at a commercial scale and enhance research efforts.

1. Introduction

The culture of marine finfish is an expanding industry in Australia. Production was ~47,600 t p.a. in 2009–10 and is currently largely based on Atlantic salmon (*Salmo salar*) farming (31,900 t) and fattening of wild-caught southern bluefin tuna (*Thunnus maccoyii*) in sea cages (7300 t) in Tasmania and South Australia, respectively (ABARES, 2011). The major emerging species currently produced from hatchery-reared stock are barramundi (*Lates calcarifer*) (3200 t), yellowtail kingfish (*Seriola lalandi*) and mulloway (*Argyrosomus japonicus*) (combined < 4900 t) (ABARES, 2011). Several other new species are under investigation as potential candidates for culture in Australia, ranging from tropical to temperate species; including flowery rockcod (*Epinephelus fuscoguttatus*) and goldspotted rockcod (*E. coioides*) (Knuckey and Cox, 2004), striped trumpeter (*Latris lineata*) (Battaglene and Cobcroft, 2007) and most recently, Southern bluefin tuna from captive broodstock (Braidotti, 2009). Reliability of supply of high quality hatchery-produced juveniles is a limiting factor for the development of the finfish aquaculture industry, coinciding with a target to increase finfish aquaculture production in Australia from 27,000 t in 2004–2005 (ABARE, 2006) to 100,000 t by 2015 (Hone, 2008).

One of the factors impacting upon the quality of hatchery-produced fish in Australia, as it is worldwide, is skeletal malformations. Larval quality rather than quantity is now a major focus of European industry development due to the estimated cost of malformations to industry of >€50 million p.a. (Hough, 2009; Koumoundouros, 2010). The emphasis on improving fish quality was demonstrated by the collaborative activity in the recently completed EU Framework Program 6 project FineFish, with 20 partners in 10 countries (Hough, 2009). A small number of studies have described malformations in marine fish from Australian hatcheries (Cobcroft and Battaglene, 2008, 2009; Cobcroft et al., 2001; Fraser and de Nys, 2005; Fraser et al., 2004; Sadler et al., 2001; Trotter et al., 2001), and one estimate of the cost to industry is AUD $1 million p.a. (~€750,000) for yellowtail kingfish (Cobcroft and Battaglene, 2008). However, until the current study the extent of malformations across the industry sector was unknown.

We assessed the magnitude of malformations in the Australian marine finfish hatchery industry via a survey of hatchery managers, asking about the occurrence of skeletal malformations in the fish produced, the impact of malformations on hatchery production, and larval rearing protocols. Samples of larvae and juveniles from participating hatcheries were analysed for abnormalities in cartilage and bone structure, and compared with survey responses. We review published reports on malformations and experiments conducted with striped trumpeter to investigate the effects of tank environment and vitamin enrichment of live feeds on jaw malformations.

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2. Materials and methods

2.1. Hatchery survey

A survey of Australian commercial and research hatcheries was conducted, requesting information on the incidence and severity of skeletal malformations, the perceived impact on hatchery production, and techniques used to rear larvae. An invitation to participate was made to the managers of 26 marine fish hatcheries, identified from industry associations, directories and research hatchery contacts. This was followed with a semi-structured telephone interview of 45 to 60 min to collect hatchery information. Participating hatcheries were invited to contribute fish samples for a 'snap-shot' of fish quality to compare with the malformation incidence reported in the survey responses. Hatchery names and incidences of malformations in individual hatcheries are not reported in the results to maintain confidentiality, except where hatcheries have specifically agreed to the public release of information. Incidences of malformations were assessed by hatcheries as part of their routine procedures and reported for the end of the nursery phase, prior to sorting if relevant, generally 50–100 mm total length (TL). The criteria for malformation assessment differed among commercial hatcheries.

2.2. Malformation assessment

To complement the hatchery survey information, separate samples of fish were collected and sent to the IMAS laboratory for independent and standardised assessment for malformations. Larvae and juveniles were randomly sampled from one or two runs sourced from at least two larval tanks by staff from participating commercial and research hatcheries in Tasmania, South Australia, Western Australia, Northern Territory and Queensland. Sampled fish were anaesthetised in 30 ppm Aqui-S® (AQUI-S New Zealand Ltd), then fixed in 10% neutral buffered formalin. Fish total length was measured, using an eyepiece graticule on an Olympus SZ dissecting microscope for fish < 20 mm TL, and were assessed for externally visible signs of malformation. Evaluation criteria, using terminology from Koumoundouros (2010) where possible, were standardised among the three assessors in the study using a subset of at least 50 larvae and juveniles of each species, then one assessor was responsible for each species and unusual cases were considered by at least two assessors. Sub-samples were randomly selected to include an age range of larvae and from different tanks, and were then cleared and stained with alcian blue for cartilage and alizarin red S for bone (Taylor and Van Dyke, 1985). The total numbers of sampled fish of each species and the numbers cleared and stained are included in the Results section. Digital images of the cleared and stained larvae were captured with an Insight Spot camera (Diagnostic Instruments Inc., USA; supplier SciTech Pty Ltd, Australia) and Image Pro Plus 5.1 software (Media Cybernetics, USA) facilitating identification of skeletal abnormalities, classified by type, position, and bones involved. The number of vertebrae and soft and hard fin rays were not included in the assessment of samples.

3. Results

3.1. Hatchery survey

Survey responses were received from 18 of the 26 invited Australian hatcheries (69%) and covered 23 species, with the emerging and new commercial species listed in Table 1. Some respondents indicated that skeletal malformations were a significant impediment to production efficiency in several species and facilities (Table 2). Maximum annual production of the surveyed hatcheries between 2005 and 2008 was in excess of 11 million fry, dominated by barramundi, yellowtail kingfish and mulloway. Overall, 44% of the responding hatcheries indicated that skeletal malformations were a significant issue. The range of malformations over the four years from 2005 to 2008 was <1 to 95% and variability between runs was reported by 16 of the 18 hatcheries (89%). All hatcheries culturing yellowtail kingfish and striped trumpeter identified malformations as a significant issue. For barramundi hatcheries, there was variability between hatcheries, with some indicating <1% and others with persistent malformations around 5%. No data were collected on the financial cost of malformations to hatchery production, although several reasons were given by hatchery managers for malformations being an important issue including; inability to sell malformed fish, labour intensive hand grading, variability and unpredictability of batches, wasted feeding and husbandry effort, feeding and weaning issues in fish with a malformed jaw. Two of the nine hatcheries to submit samples indicated in the survey that malformations were not a significant issue, although the analysis of samples from these hatcheries revealed > 5% severe malformations. According to the > 5% criteria, this increased the number of hatcheries with a malformation issue to 10 out of 18 (56%).

Australian hatcheries employ different water treatment and culture methods (Table 3). More than half of the hatcheries filter incoming water to ≤10 μm and most disinfect the water for larval rearing with either UV, chlorination and dechlorination, or ozonation. Larval culture is undertaken in intensive, semi-intensive and extensive systems. Only one responding hatchery used clearwater and the remainder employed the greenwater method with about half of those using live algae and half using commercial algal pastes. Greenwater in tanks was managed with either a static system where the tanks were drained down and topped-up with water as required (described by Palmer et al., 2007), with flow-through or with recirculation. Copepods were utilised in pond culture and intensive rearing systems in four hatcheries, and most facilities used commercial enrichment products (fish oil based emulsions or freeze dried algae) for rotifers and *Artemia*, although seven facilities used live or paste algae for rotifer enrichment.

Table 1
New and emerging species produced for marine finfish aquaculture by Australian hatcheries surveyed in this study. Common names are according to Australian Standard Fish Names.

Species		
Common name	Scientific name	Family
Yellowtail kingfish	*Seriola lalandi*	Carangidae
Jungle perch	*Kuhlia rupestris*	Kuhliidae
Barramundi	*Lates calcarifer*	Latidae
Striped trumpeter	*Latris lineata*	Latridae
Mangrove jack	*Lutjanus argentimaculatus*	Lutjanidae
Sea mullet	*Mugil cephalus*	Mugilidae
Australian bass	*Macquaria novemaculeata*	Percichthyidae
Dusky flathead	*Platycephalus fuscus*	Platycephalidae
Greenback flounder	*Rhombosolea tapirina*	Pleuronectidae
Cobia	*Rachycentron canadum*	Rachycentridae
Mulloway	*Argyrosomus japonicus*	Sciaenidae
Southern bluefin tuna	*Thunnus maccoyii*	Scombridae
Barramundi cod	*Cromileptes altivelis*	Serranidae
Goldspotted rockcod (gold spot grouper)	*Epinephelus coioides*	Serranidae
Flowery rockcod (flowery grouper)	*Epinephelus fuscoguttatus*	Serranidae
Queensland groper	*Epinephelus lanceolatus*	Serranidae
Black rabbitfish	*Siganus nebulosus*	Siganidae
King George whiting	*Sillaginodes punctata*	Sillaginidae
Sand whiting	*Sillago ciliata*	Sillaginidae
Yellowfin bream	*Acanthopagrus australis*	Sparidae
Black bream	*Acanthopagrus butcheri*	Sparidae
Snapper	*Pagrus auratus*	Sparidae
Sooty grunter	*Hephaestus fuliginosus*	Terapontidae

Names in brackets are used in other literature.